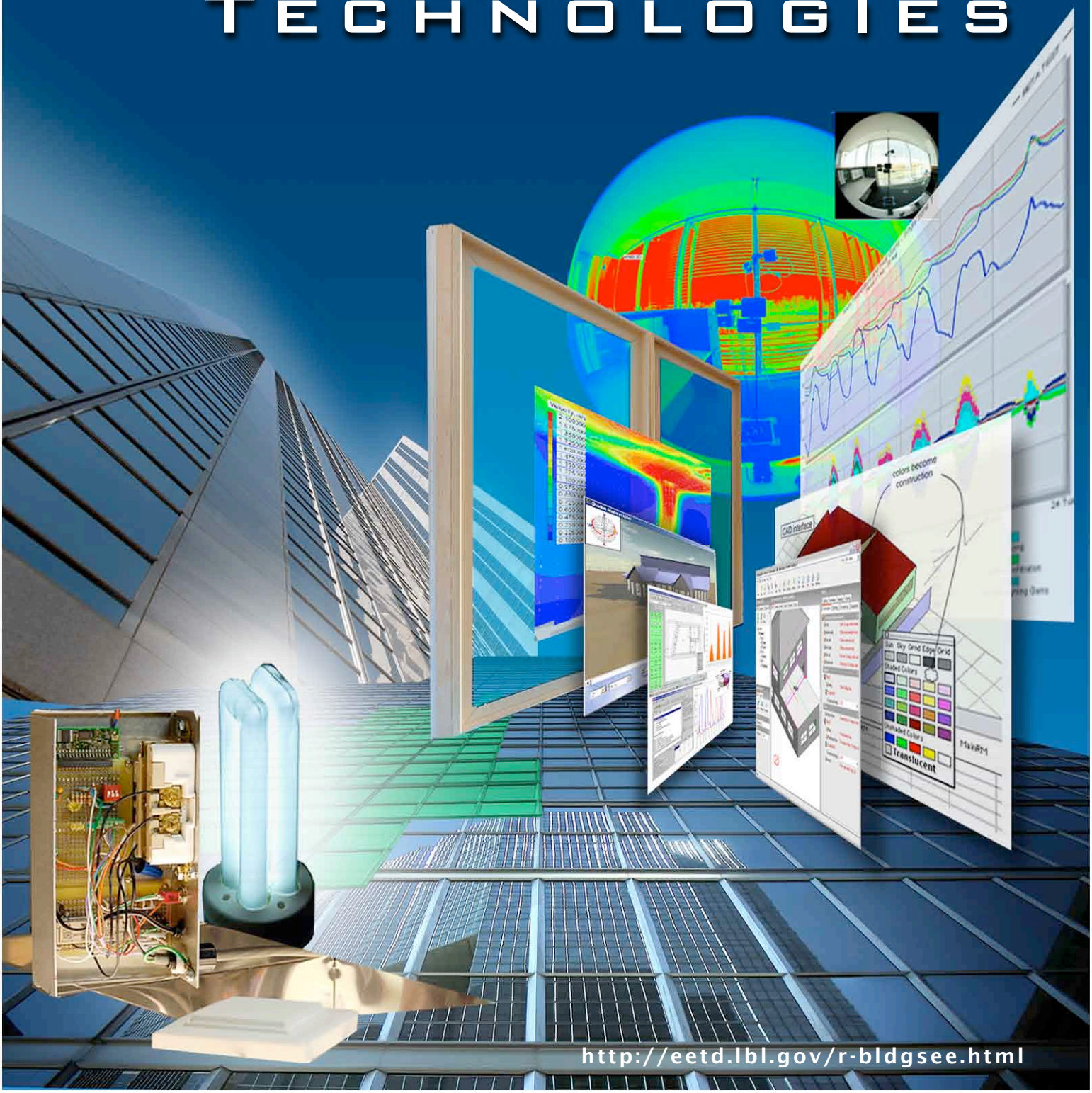
Lawrence Berkeley National Laboratory

Environmental Energy Technologies Division

2011

Building Technologies



http://eetd.lbl.gov/r-bldgsee.html

Building Technologies Department

Buildings in the U.S. use 40 percent of U.S. energy and emit 40 percent of U.S. greenhouse gases. To reduce GHGs and counter climate change, it is necessary to develop methods that substantially reduce GHG emissions from buildings.

The goal of 21st century research on energy-efficient buildings is to develop design, construction, and operational technologies and practices that lead to the construction of net zero energy buildings (NZEBs). Those buildings will use 70 percent less energy than today's average, with the remaining energy use supplied by clean, sustainable energy sources. By 2030, every new building should be a net-zero energy building, by 2050, 50 percent of all existing buildings should be retrofit to this level.

Division researchers work closely with industry to develop efficient technologies for buildings that reduce energy bills while improving the comfort, health, productivity, and safety of building occupants.

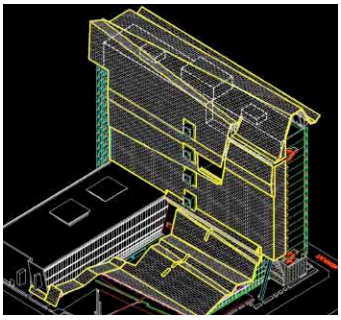
Our efforts focus on developing the following:

- **A building operating platform that can be used to design and simulate net-zero energy buildings**
- **Simulation models and benchmarking tools to evaluate efficiency and whole building systems and components**
- **Whole-building and system diagnostics and energy information systems**
- **Advanced control systems and sensors for NZEBs**
- **Windows, daylighting, and lighting control systems**
- **Automated demand response communications and load-reduction technologies for the smart grid**
- **Energy-efficient high-technology buildings, including data centers, labs, and cleanrooms**
- **Demonstrations and deployment strategies of advanced commercial building systems through high-profile R&D partnerships**

Research Areas

Commercial Buildings

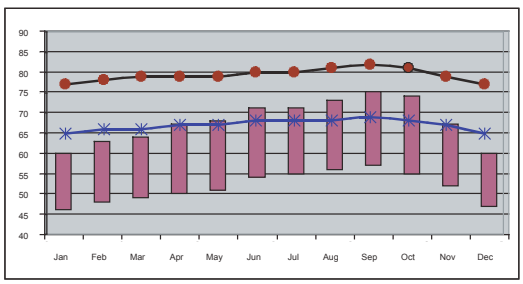
Advanced Commercial Building Systems and Simulation Research



Central to the goal of the net-zero energy building is developing the *Building Design and Operating Environment* that will allow architects and engineers to perform model-based system engineering for building design and operation. It consists of a *Building Design Platform,* a *Building Operating Platform,* and a supporting *Building Informatics Repository*.

The Building Design Platform generates design information that specifies the design and its corresponding energy performance. This information is used by the Building Operating Platform to configure the control system and test the implementation of algorithms used in various aspects of operation. The Building Informatics Repository will contain simulation tools, model libraries and algorithms for control and optimization that support both the Building Design Platform and the Building Operating Platform.

Under the platform, building operators will have access to information about how the building is designed to operate, as well as benchmarks to assess the day-to-day energy performance of their buildings, and to maximize energy efficiency and building comfort in real time—something that few facilities managers have today. Research to develop these software tools is in its early stages.



http://cbs.lbl.gov/
http://buildings.lbl.gov/

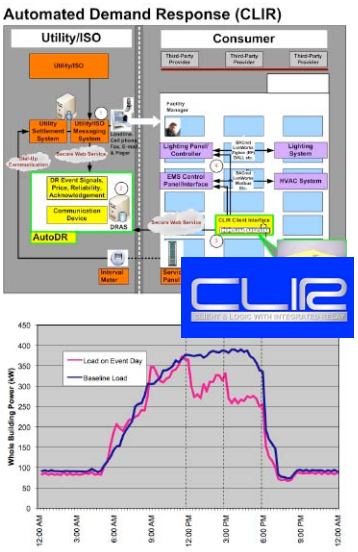
Buildings researchers at Berkeley Lab began developing a model to simulate the energy use of buildings in the 1970s. DOE-2 became the de facto standard in the buildings community. It has been superseded by EnergyPlus, which models heating, cooling, lighting, ventilating, and other energy flows as well as water in buildings, and whose development is also led by buildings researchers in the Division's Building Technologies Department. Originally based on the most popular features and capabilities of DOE-2 and other programs, EnergyPlus includes many innovative simulation capabilities, such as time steps of less than an hour, modular systems and plant integrated with heat balance-based zone simulation, multizone air flow, thermal comfort, water use, natural ventilation, and photovoltaic systems.

Demand Response

Demand Response Research Center

The Demand Response Research Center (DRRC) was launched at Berkeley Lab by the California Energy Commission's Public Interest Energy Research (PIER) Program in 2004 to support all forms of demand response R&D. The DRRC manages a portfolio of research projects that address demand response pricing, valuation, and behavior, as well as building-to-grid interfaces and technologies.

Demand response (DR) is the customer's process of managing electricity use dynamically upon receiving a notification from the electric utility or independent system operator (ISO) that indicates the grid is near capacity—for example, when too many air conditioners are on during a hot summer's day. Customers who enroll in a utility's DR program decrease their building's electricity usage by reducing lighting, cooling, or other loads. This reduction may last from 5 minutes to several hours, depending on the constraints of the grid.



Automating this process ensures timely and persistent participation. DRRC researchers have developed OpenADR, an open and interoperable automated communications platform that links the electric grid operations with a facility's energy management and control systems. Customers pre-program their energy management strategies for the DR period, and those strategies are dispatched upon the receipt of price, reliability, or emergency signals from the electricity grid.

Use of OpenADR is expanding in California, thanks to the California Public Utility Commission's interest and a partnership between the DRRC and California's investor-owned utilities. OpenADR has also been used in Seattle in coordination with Seattle City Light and the Bonneville Power Administration. The public specification known as "OpenADR Version 1.0" is being formalized in the National Institute of Standards and Technology (NIST) smart grid standards process. It is one of the key technologies to enable price- and reliability-based demand response for the U.S. and abroad.

http://drrc.lbl.gov

Commissioning, Fault Diagnostics, and Energy Information Systems

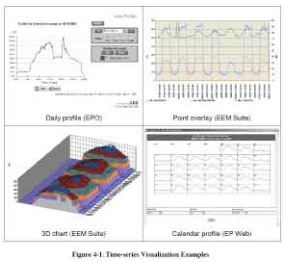
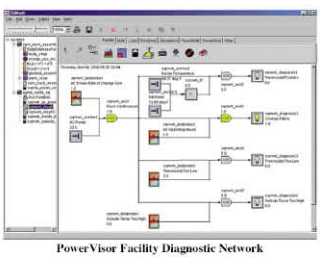


Figure 4-1. Time-series Visualization Examples

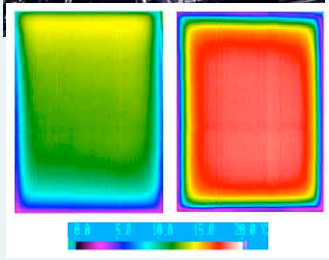


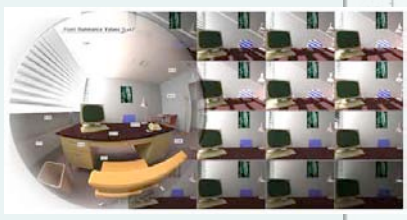
PowerVisor Facility Diagnostic Network

Energy is wasted in commercial buildings when equipment is not well controlled, maintained, scheduled, or calibrated. EETD researchers have developed tools, case studies, diagnostic methods, and energy information systems to help identify and reduce energy waste.

http://eis.lbl.gov

Windows, Daylighting, and Lighting Controls





Every year, heat worth billions of dollars flows through windows in American homes and businesses. In hot climates, the heat radiates into homes, requiring expensive air conditioning. In cold climates, it leaks out, requiring more energy to keep the occupants warm. Thermally efficient windows save consumers and businesses energy and money.

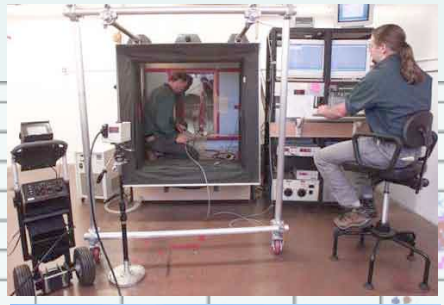
EETD's researchers develop advanced optical coatings and materials for future windows; study the energy performance of windows and window systems (windows, glazings, and their frames, blinds, louvers, etc.); and create computer tools to improve window energy performance and support product rating and labeling.

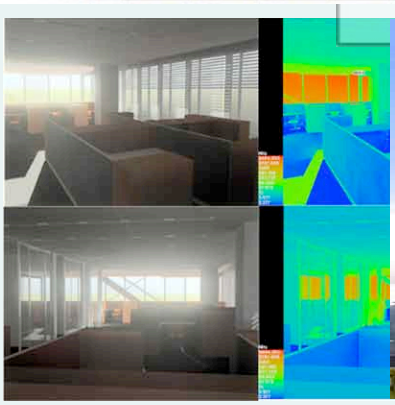
EETD's infrared thermography lab is used to study the thermal and insulating properties of new windows, materials, and building envelope systems.

Advanced daylighting designs allow natural light to be used effectively, reducing the need for electric lighting. Optimal use of natural daylight requires advanced lighting controls that sense light levels and occupancy.

A unique lab whose construction was funded by the California Energy Commission's Public Interest Energy Research, the Advanced Windows Test Facility serves as the primary test facility for prototype systems such as electrochromic windows, automated motorized blinds, and advanced controls for these systems.

http://windows.lbl.gov





Modeling and Simulation of Building Energy and Control Systems

To achieve the next leap in building energy efficiency, buildings will need to integrate information from air-conditioning systems, lighting systems, and the electrical grid to regulate their operation to optimize occupant comfort, energy use, and peak power demand. Scientists in the Simulation Research Group, and their colleagues at UC Berkeley are developing software that will allow building scientists and designers to use virtual prototyping to explore and optimize new system-level solutions for space conditioning and to develop and assess the performance of control systems that minimize environmental impact while maintaining occupant comfort. This same software, used as part of the building control system, will allow operators to maximize efficiency and monitoring the operation of their building.

EETD scientists are integrating through the Building Controls Virtual Test Bed various software environments, such as the next-generation open-source modeling language Modelica; the University of California (UC), Berkeley-developed modeling environment Ptolemy II; and EETD-developed software such as EnergyPlus and Radiance. These programs can then be used for integrated design studies as well as model-based operation when linked to BACnet compatible building control systems.

EnergyPlus

EnergyPlus is an advanced computer program that simulates hourly building energy use. This program is an international benchmark and is used as the basis of building standards in the U.S. and other countries. EnergyPlus combines the best features of the DOE-2 and BLAST programs into a new, powerful, and more accurate program.

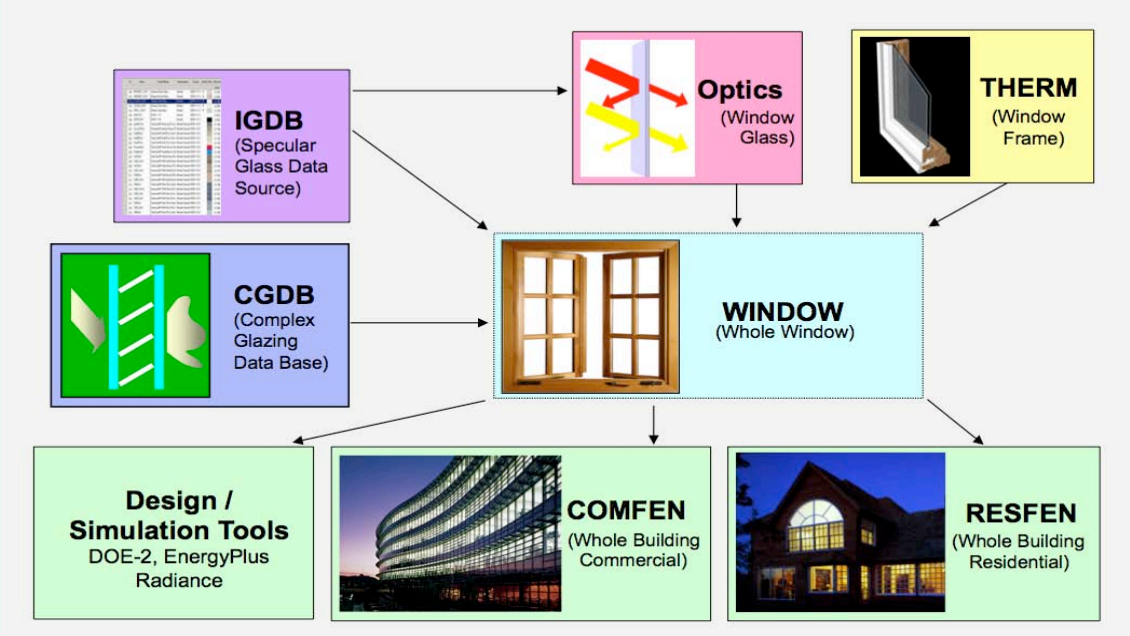
EnergyPlus features a heat balance loads calculation, a simultaneous loads and HVAC calculation, sub-hour time steps, moisture absorption/desorption in building elements, loop-based HVAC systems, a new input data structure that allows easy attachment of graphical user interfaces, a modularized code that allows others to easily add new calculation features, and a new output data structure that allows easy attachment of post-processors for results display and analysis.

http://apps1.eere.energy.gov/buildings/energyplus/
http://gundog.lbl.gov/EP/ep_main.html

Home Energy Saver

Home Energy Saver is the first Internet-based tool for calculating energy use in residential buildings. The project is sponsored by the U.S. Environmental Protection Agency and the U.S. Department of Energy as part of their national ENERGY STAR programs for improving energy efficiency in homes.

http://hes.lbl.gov/



COMFEN

COMFEN is a tool designed to support the systematic evaluation of alternative fenestration systems for project-specific commercial building applications. COMFEN provides a simplified Excel-based user interface that focuses attention on key variables in fenestration design. Under the hood is EnergyPlus, a sophisticated analysis engine that dynamically simulates the effects of these key fenestration variables on energy consumption, peak energy demand, and thermal and visual comfort.

The results from the EnergyPlus simulation are presented in graphical and tabular format within the simplified user interface for up to four comparative fenestration design cases, to help users move toward optimal fenestration design choices for their project.

http://windows.lbl.gov/software/comfen/2/

RESFEN

RESFEN (RESidential FENestration) is a program for calculating the annual heating and cooling energy use and costs attributable to fenestration systems in residential buildings. RESFEN also calculates their contribution to peak heating and cooling loads.

http://windows.lbl.gov/software/resfen/resfen.html

RADIANCE

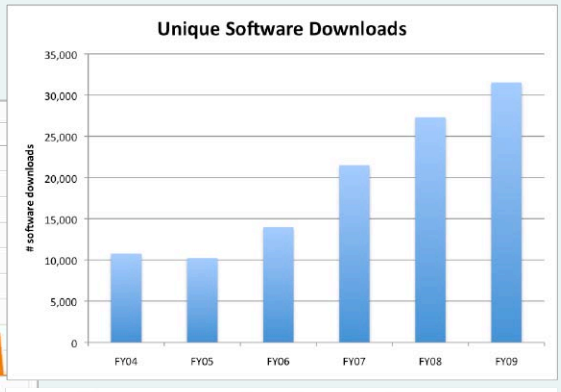
RADIANCE is a photometrically accurate computer-generated graphic simulation of lighting in indoor environments. The ultra-realistic images produced by the program facilitate the designer's visualization of lighting design options.

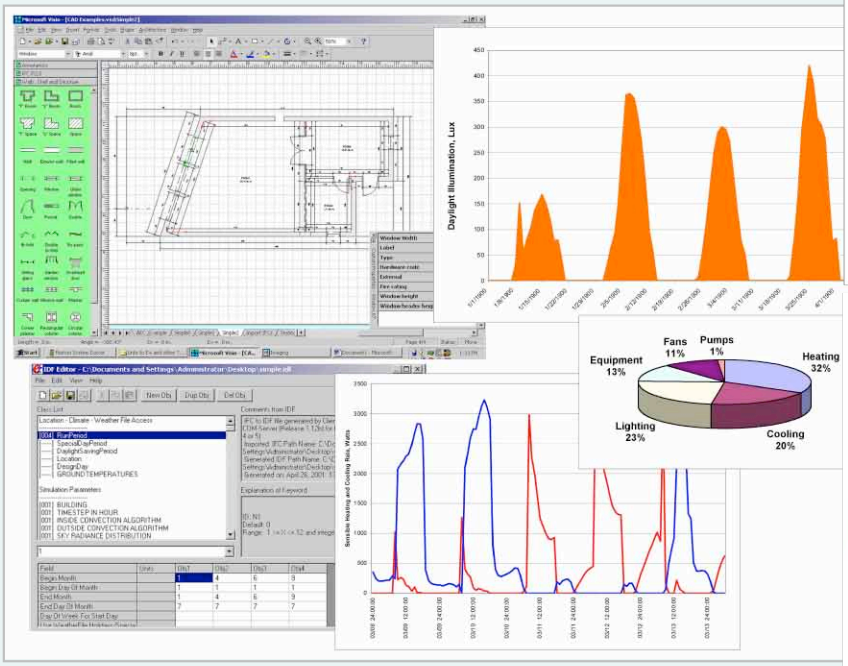
http://radsite.lbl.gov/radiance/home.html

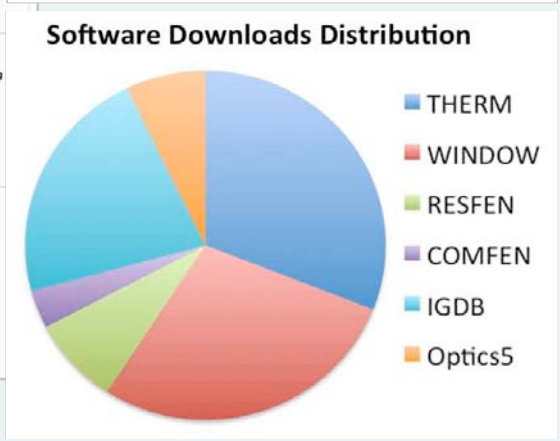
WINDOW

WINDOW is a window thermal analysis computer program that is the de facto standard used by U.S. manufacturers to characterize product performance. The program has been selected by the newly formed National Fenestration Rating Council as the basis for development of energy rating labels for windows.

http://windows.lbl.gov/software/window/window.html







High Technology Buildings

Characterized by large base-loads operating 24 hours a day with energy intensities much larger than typical commercial buildings, high-tech buildings include laboratories, cleanrooms, and data centers. An integrated design and build approach has the potential to reduce energy use in these buildings 30 to 50 percent.

California laboratory-type facilities alone use 111 trillion BTU of energy each year, including 8.8 billion kilowatt-hours of electricity (equivalent to 2,100 megawatts of peak electrical power) and 21 TBTU of natural gas, at a cost of $700 million—the potential savings from advanced design and technology in these buildings are huge.

EETD's high-tech buildings program conducts research on technologies and design, and works with partners such as the U.S. Department of Energy, U.S. Environmental Protection Agency, and the California Energy Commission on field tests and deployment programs. It has investigated and developed such technologies as DC-powered data centers, high-performance fume hoods, efficient power supplies, efficient fan units, and mini-environments for cleanrooms. It has also developed laboratory and data center energy benchmarking tools to identify energy waste and efficiency targets.

http://hightech.lbl.gov

Building Technologies

Cool Roofing Materials and Urban Heat Islands

Cities are urban heat islands, zones of higher temperature relative to the surrounding countryside. The heat island effect intensifies the use of expensive air conditioning. Higher outdoor air temperatures also increase smog formation. Division researchers have pioneered an effective, simple approach to keeping cities cooler—the use of shade trees and solar reflective roofing and paving materials. EETD studies have found that the cooling effect from wide application of these measures could save billions of dollars and reduce smog in large cities nationwide.

A program to develop cool-colored roofing materials in cooperation with the roofing industry has resulted in an entire class of new products now in the marketplace: cool, solar-reflective metal, clay, concrete tiles, and asphalt shingles that reduce air conditioning energy use by up to 20 percent by reflecting more of the sun's heat back to space.

http://coolcolors.lbl.gov/
http://heatisland.lbl.gov

Distributed Energy Resources and Energy Storage

Distributed energy resources (DER) are technologies that provide energy close to the energy consumer; for example, small power generators including renewable sources, energy storage units, interconnection and power control technologies, and combined heat and power technologies. DER could help buildings become net-zero energy users. EETD researchers are developing methods and tools for assessing the use of DER by customers operating as a microgrid, a group of energy sources and users that are connected to the larger electricity grid, but can function independently of it. Researchers have developed a customer adoption model (DER-CAM) for on-site electricity and heat requirements that helps customers develop an optimal plan to meet their energy need at minimum cost over a test period. They are also testing the microgrid concept in cooperation with utility and commercial partners.

http://eetd.lbl.gov/EA/EMP/der.html
http://der.lbl.gov

Examples of Achievement

Electronic Ballasts

The Division's lighting team worked with manufacturers to develop electronic ballasts, a more efficient replacement for the magnetic ballasts used to control the current in fluorescent lamps. Electronic ballasts now account for 32 percent of the market, saving hundreds of millions of dollars per year.

Low-Emissivity Coatings for Windows

In the 1980s, EETD researchers worked with window manufacturers to develop special "low emissivity" window coatings to reduce heat loss through windows. These windows, which reduce energy loss by 20 to 50 percent depending on the design, now account for more than half of the market and have saved billions of dollars in energy costs.

Information and Monitoring-Based Commissioning

During the mid-1990s the commercial buildings team deployed and evaluated high quality monitoring platforms to help understand how building operators can benefit from improved energy information. Monitoring-based commissioning is now a major utility-funded efficiency program in California and is being deployed throughout the U.S.

Building Energy Simulation

One of the Division's first projects, in the 1970s, was the development of a computer program to simulate the energy use of buildings based on prospective designs. Architecture and engineering firms use DOE-2 to increase the energy efficiency of their designs, saving an average of 20% of building energy use. In the 1990s, EETD researchers and colleagues combined DOE-2 with features of other building software programs, creating EnergyPlus—a more versatile, sophisticated model that has become the new de facto standard.

Energy Auditing for Consumers

In the first-ever such use of the Internet, a program called Home Energy Saver (HES) is available to anyone with web access (http://HES.lbl.gov). The user inputs information about a home, and HES (using DOE-2) calculates total energy use and cost, and suggests economic ways of reducing the energy bill. Since its beginnings in the late 1990s, Home Energy Saver has served more than a quarter of a million homeowners and apartment dwellers.

Contacts

Stephen Selkowitz
Telephone: 510-486-5064
Email: SESelkowitz@lbl.gov

Mary Ann Piette
Telephone: 510-486-6286
Email: MAPiette@lbl.gov

Visit the Lab: www.lbl.gov

Visit the Building Technologies Department, Environmental Energy Technologies Division:
http://eetd.lbl.gov/r-bldgsee.html

The mission of Berkeley Lab's Environmental Energy Technologies Division is to perform research and development leading to better energy technologies that reduce adverse energy-related environmental impacts. Our work increases the efficiency of energy use, reduces its environmental effects, provides the nation with environmental benefits, and helps developing nations achieve similar goals through technical advice.

February, 2011